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Physical mask

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Published in:
9th International Conference of European Society of Precision Engineering and Nanotechnology

Publication date:
2009

Citation (APA):
Islam, M. A., & Hansen, H. N. (2009). Physical masking process for integrating micro metallic structures on polymer substrate: Physical mask. In *9th International Conference of European Society of Precision Engineering and Nanotechnology: EUSPEN* (1st ed., Vol. 2nd, pp. 22-25). Euspen-Copy & Druck.

Physical masking process for integrating micro metallic structures on polymer substrate

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Abstract

Integration of micro metallic structures in polymer devices is a broad multi-disciplinary research field, consisting of various combinations of mechanical, chemical and physical fabrication methods. Each of the methods has its specific advantages and disadvantages. Some applications like surface plasmon devices need micro metallic structures on a polymer substrate with a uniform metal layer thickness in the nanometer range. A well known fabrication process to achieve such metallic surface pattern on polymer substrate is photolithography which involves an expensive mask and toxic chemicals. The current study shows a novel approach for fabricating thin micro metallic structures on polymer substrates using a simple physical mask and PVD equipment. The new process involves fewer process steps, it is cost effective and suitable for high volume industrial production. Current study suggests that physical masking process in combination with PVD can be a cost effective alternative to photolithography when thin metallic structures on a polymers substrate are concerned.

1 Introduction

A conventional mask making process is photolithography which uses toxic chemicals and involves many steps. The current study investigates on manufacturing of a simple physical mask and to use that mask for Physical Vapor Deposition (PVD) of metal on the polymers substrates. The end product would be used for applications like surface plasmon resonance (SPR) sensors. The concept is schematically presented in Figure 1 and the following experimental section describes the process steps and summarizes results and discussion.

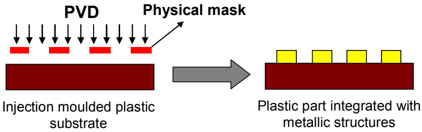

Figure 1: Process steps for physical vapor deposition of metal on polymer substrate.

2 Experimental investigation

The objective of this experiment is to prove the feasibility of fabricating thin micro metallic structures on polymer substrates using physical mask and a PVD equipment to be used as alternative fabrication methods for SPR sensors as the method currently used is expensive and utilizes toxic chemicals.

2.1 Materials, methods and equipment

For this investigation two different plastic materials were used for bulk substrate (PS 143E from BASF and PC 143R from SABIC. The test geometry for the bulk plastic substrate was 135×25×2 mm injection moulded flat part. For mask making 100 µm thick Aluminum (Al) foil was used. The chosen mask geometry was two lines of 40 µm width 2 mm apart from each other. The lengths of two lines were 5 mm and 2.5 mm respectively. The equipment used to produce the mask was SARIX micro electro discharge machine (SX-200-HPM 3D µ-EDM milling machine). The PVD equipment used in the experiment was a "Metallux" model "ML18" with an oil-diffusion pump (see Figure 2). PVD operation was done both on substrates covered with mask and without mask. The mask was mechanically attached to the substrate.

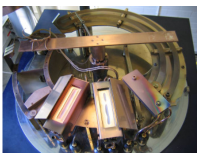

Figure 2: PVD chamber outside (let picture) and PVD chamber inside (right picture).

2.2 Results and discussion

One of the most important parts of this experiment was the mask production. Technically it was challenging task and the main problem associated with this task was the breakage of electrode in the micro dimensional scale. After several trials and errors the Al foil mask with two straight lines was fabricated by µ-EDM. The line produced by µ-EDM is shown in the following figure.

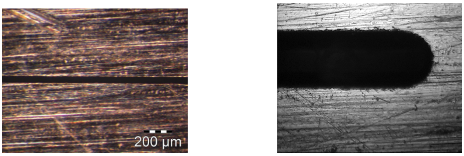

Figure 3: Al mask machined by µ-EDM (line end shown in the right picture).

The measurement of the line widths was carried out in three different spots along the length of the line by coordinate measuring equipment (Demeet 220). The widths of the individual line at different sports were identical within ±3 µm. But there was difference in the line widths (in the range of few microns, see Figure 4) of the two lines. The reason for it was mainly the erosion of electrode and the spark gap associated with the EDM process.

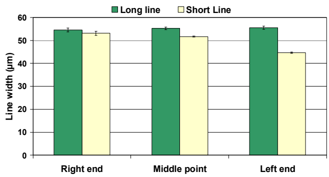

Fig 4: Measurement of the line widths (on the mask).

PVD coating was successfully done on both PS and PC substrate applying the mask. Figure 5 shows the selectively coated surface of PS. The width measurement of PVD coated lines were carried out approximately on the same spots as it was done in case of the mask. Figure 6 shows the comparative line widths of two different lines with respect to the mask width. The figure shows that the lines are wider on the substrate than on the mask. The reason for this is the leakage of material in the PVD process between the mask and substrate. A tighter clamping between the mask and substrate could make the line width similar on the substrate surface as it is on the mask.

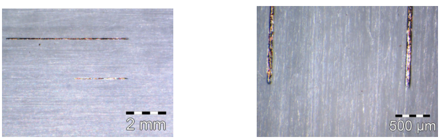

Fig 5: PVD coated PS substrate (two lines are copper layers deposited by PVD process through the mask).

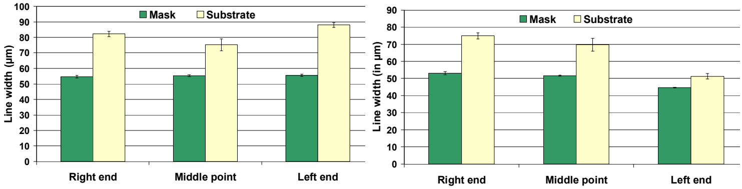

Fig 6: Line width measurement on the PVD coated sample (long line-left picture, short line-right picture).

The adhesion between the polymer substrates and metal was characterized with tape test and Pull test. Detail about the adhesion test method can be found in reference [2]. The adhesion between PS and Cu was good (higher than 5 MPa). But it was not possible to characterize the exact adhesion force due to glue failure (see Figure 7).

Fig 7: Samples after fail the tape test (material PC+Cu)-left picture, glue failure between the Cu surface and test element (material PS+Cu)-right picture.

3 Conclusion

Experiments prove the feasibility of PVD operation in combination with physical mask manufactured by µ-EDM process. The mask feature size is very much governed by the EDM process. Experiments also show that a tighter clamping is necessary between the substrate and mask to prevent the shadowing effect and to get the exact dimension of line width. General conclusion from these experiments is mask produced by µ-EDM can replace the lithographic mask for some application where the dimensional requirements do not fall below 50 µm approximately.

References:

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Acknowledgement: The Danish Strategic Research Council has supported the work in the project "Plasmonic Optical Chips for Medical Diagnostics and Chemical Sensing (no: 2106-05-0033)".